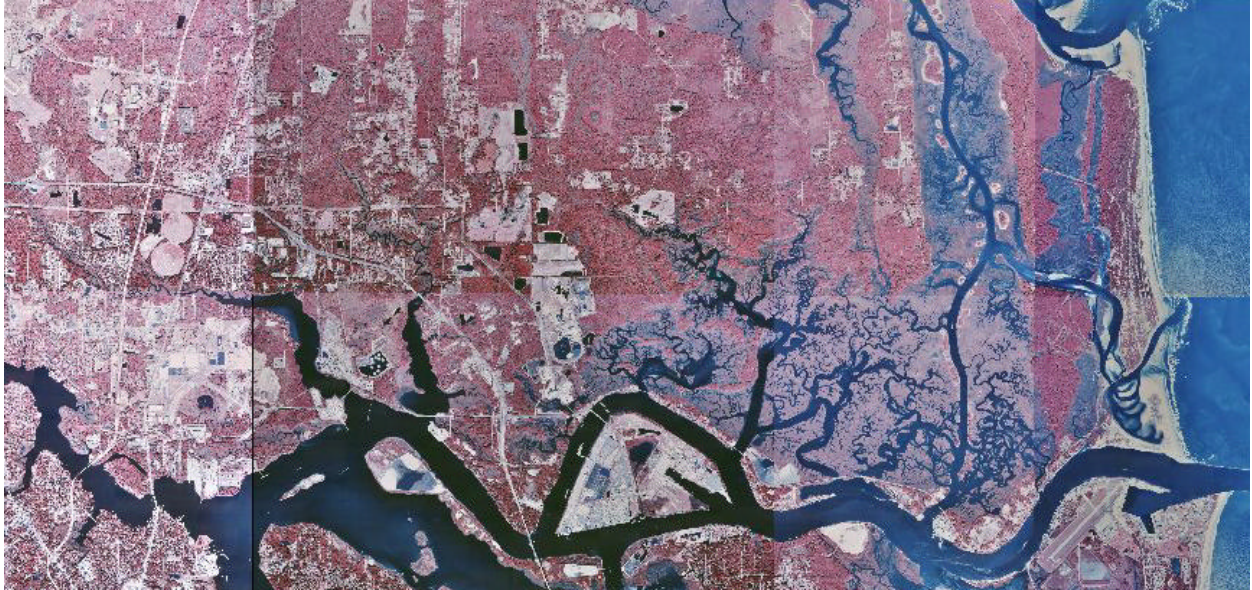


Section I



Urbanization and Freshwater Input Influences on Tidal Creek Fish Assemblages of the lower St. Johns River, Florida

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Introduction

Continued population growth (13% in Florida since 1990) puts extreme pressures on maintaining natural coastal habitats. As more and more land is being used for coastal development there is a need to better understand the functions of marsh systems in the urban environment. Our understanding of fish assemblage structure and function is still limited in the upper portions of estuaries where oligohaline to mesohaline conditions exist. Estuaries are important to fishery production (Boesch and Turner, 1984) and coastal marshes with oligohaline conditions are extremely important as nursery areas (Weinstein, 1979; Rozas and Hackney, 1983).

Over the last 30 years agricultural development was the most significant cause of wetlands loss, yet urban development is proceeding rapidly, becoming a more prevalent factor (Frayer and Whilen, 1990). Urbanization can cause wetland degradation through physical destruction of habitat, dredging for navigation, bulkheading shorelines to reduce erosion, increased salinity due to alterations in freshwater inflow, and eutrophication via nutrient input from sewage treatment and fertilizer runoff. Odum (1970) recognized the sensitivity of estuaries to alteration and the indirect effects of anthropogenic change, such as alteration in freshwater flow. Freshwater inflow is one of the most influential factors affecting estuarine community structure with impacts including declines in livable habitats and decreased diversity (Sklar and Browder, 1998). Hydrologic alteration has changed stream fish assemblages (Poff and Allan, 1995) and salinity has a pronounced effect on estuarine faunal composition (Ross and Epperly, 1985). In estuaries the subtidal habitats have the greatest species richness thus may be sensitive to hydrologic alteration. The fish assemblage has been identified as an indicator of direct and indirect stresses on the aquatic ecosystem (Fausch et al., 1990). Lower species richness and diversity has been documented in polluted estuaries (Bechtel and Copeland, 1970; Haedrich and Haedrich, 1974; Felley and Felley, 1986). Here we compare four tidal creeks that differ in levels of development and freshwater input to assess the role of these two factors on structuring of the tidal creek fish assemblage. We used the patterns of faunal composition and abundance to evaluate impacts of development on these assemblages.

Study Area

The lower reaches of the St. Johns River forms a complex river mouth estuary composed of deltanic deposits dissected by meandering tidal creeks and salt marsh. This area is part of the last great salt marsh area along the eastern United States coast. It is composed of expanses of cordgrass (*Spartina alterniflora*) and needlerush (*Juncus roemerianus*). While the two major rivers, St. Johns to the south and the lesser Nassau River to the north, encompass this marsh area, upland drainage into tidal creeks also contribute significantly to freshwater input. The St. Johns River is the largest in Florida, but it has low flow and thus little sediment transport. Holocene sand deposits dominate to the east behind beach ridges with Pleistocene marine terraces to west (Hayes, 1984). Sediments grade from sandy bottom near the coast to sandy-mud in land. Tagatz (1968) described the ichthyofauna of the main stem of the St. Johns River but little is known about marshes and tidal creeks feeding the river. Four tidal creeks on the north shore of the St. Johns River were sampled as follows, from west to east: Broward River, Dunn Creek, Clapboard Creek, and Cedar Point Creek (Figure 1). Anthropogenic impacts decreased from west to east moving from upstream to downstream. Table 1 lists levels of impact and water quality assessment for each creek. Broward River disturbance was high with the headwaters draining the southern part of Jacksonville International Airport and dense residential and heavy industry along the shores with a paper processing plant and oil terminal at the mouth. Dunn Creek is characterized by moderate residential and agricultural development. Between Dunn and Clapboard lies the Jacksonville power plant. Clapboard Creek development was minimal with only light residential and agricultural activity. The lower half of Clapboard Creek is in the National Park Service Timucuan Ecological and Historic Preserve (TEHP). Cedar Point Creek had the smallest drainage basin with light residential development. It is completely encompassed by the TEHP. Cedar Point Creek has been modified by road development restricting flow into St. Johns River to a 76-cm diameter culvert. Unrestricted flow was accessible through connections to Clapboard and Sister's Creek (Figure 1). The middle to lower reaches of Clapboard and Cedar Point creeks have oyster reef development along the banks with greatest development in Cedar Point Creek.

The area has the highest tidal range along Florida Atlantic coast but less than the maximum range in the Georgia Bight (Nummedal et al., 1977). During the sampling periods tides range from 0.93-1.67 m with highest water in December.

Table 1. Tidal creek characteristics.

Creek	Drainage Area (ha)	Wetlands Area (ha)	Land Use Categories			Water Quality ¹
			Industrial	Residential	Agricultural	
Broward	7514.7	337.1	Moderate	Dense	None	Fair
Dunn	6053.6	447.3	None	Moderate	Moderate	Good
Clapboard	2762.7	1109.1	None	Light	Light	Fair
Cedar Point	921.7	713.2	None	Light	None	Fair

¹Water quality assessment from Hand et al. (1996).

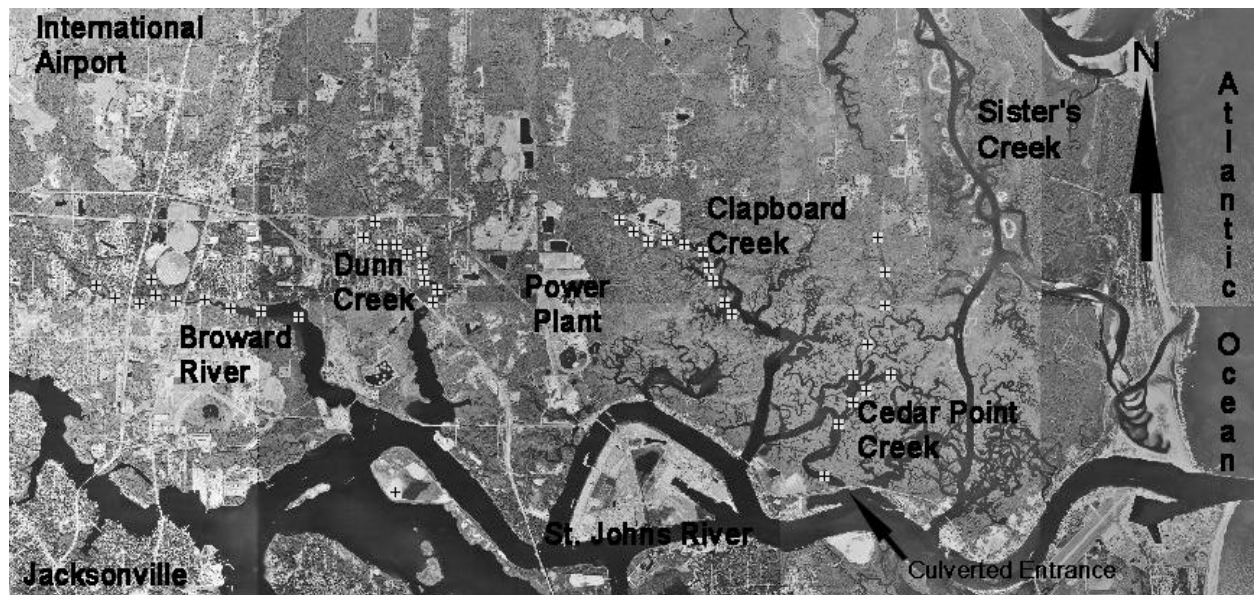


Figure 1. Map of study creeks with sampling locations marked with crosses.

Methods

Ten sampling sites were randomly selected in the upper and middle reaches of four creek: Broward River, Dunn Creek, Clapboard Creek, and Cedar Point Creek. As Cedar Point Creek was short, sampling sites covered all portions of the creek. At each site a starting point was randomly selected its location determined by hand-held GPS. One set of hydrological parameters (temperature, salinity, and dissolved oxygen) was measured near the bottom at each site using portable instruments (YSI model 33 and 57). A 3-m otter trawl with 6-mm mesh body and 3-mm mesh liner was employed to sample along the middle of each site, either the middle of the creek channel or within open embayments along the creeks. Four sequential non-overlapping 2-min tows were made at each site. Tow speed was maintained at around 3.7 km/hr covering approximately 1200 m per tow. Fish were sorted to the lowest possible taxa in the field, identified, enumerated, and up to 30 measure for standard length. Most fish were released after the first sampling period and thereafter only retained if identification was in question. All retained specimens were preserved in 10% formalin and returned to the laboratory for further examination.

Four periods were selected to sample to wet and dry periods and coldest and warmest parts of the year. Samples were taken in warm season in July (17-19 and 28-31) 1996, cool –wet in December (14-17) 1996, cool-dry in February (13-16 and 23-24) 1997, and transitional April (19-22) / May (14-15) 1997 (Figure 2). Sampling was scheduled around the diurnal high tide. Protracted sampling in April/May due to logistical problems resulted in missing samples at some stations. Primary production peaks in June and July in the St. Johns River estuary (DeMort and Bowman, 1985).

Data Analysis

Community parameters, total number of individuals, number of demersal fish, number of taxa, Shannon-Weiner diversity, and Pielou's evenness were compared among creeks using a two-way fixed effect ANOVA with season and creek as factors. In addition, the five most abundant taxa were compared with the same model. Each trawl tow was considered a replicate sample and although sites were revisited, starting locations were different in each season.

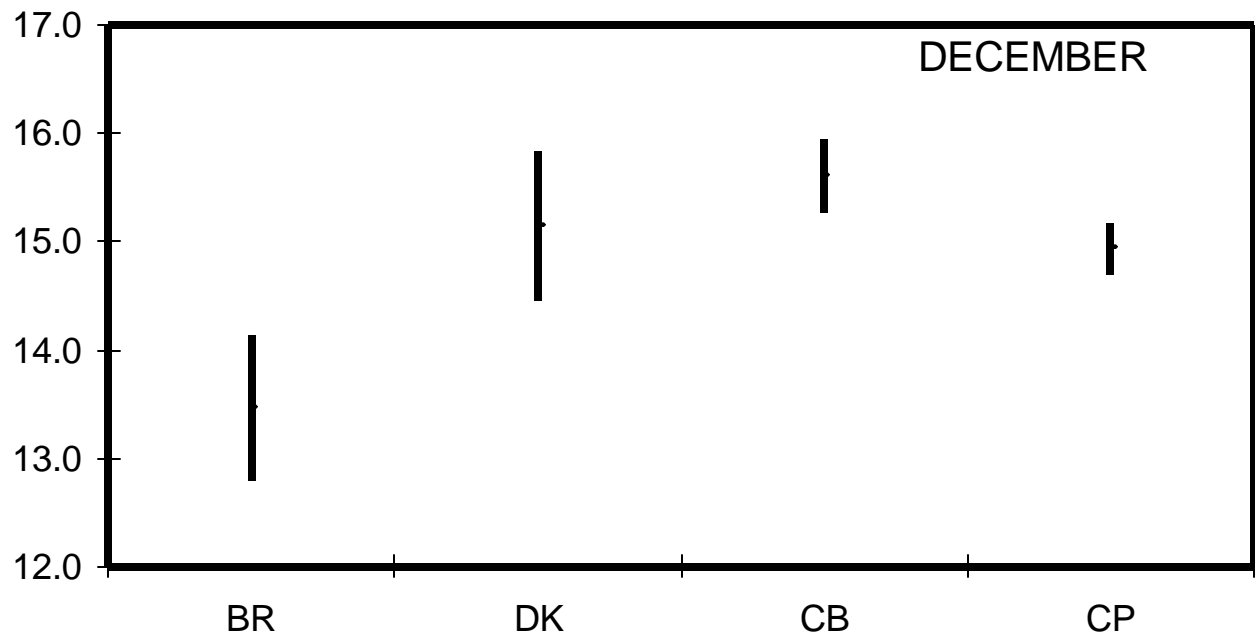


Figure 2. Climatological data for 1996-1997 from Jacksonville International Airport (National Climate Data Center, 1996, 1997). Sampling periods marked by vertical dashed lines.

Overall community comparisons were made using abundance summed by creek and season. We used COMPAH (Gallagher, 1998) to cluster creeks by season and taxa. The similarity measure CNESS ($m=4$), a generalized form of the Morisita index, (Trueblood et al., 1994) was used to relate entities and a UPGMA sorting strategy was used to graphically show the relationships (Boesch, 1977). Detrended correspondence analysis (DCA) was performed on taxa using the complete station by season data using CANOCO (Ter Braak, 1995). A polynomial model was fit to the data using the top 43 taxa.

Results

Water temperature was greatest in July 1996 and lowest in December 1996 through February 1997 as expected (Table 3). July had high variability conditions among stations with increasing temperature from inland (Broward River) to coastal (Cedar Point Creek) (Figure 3). A similar pattern occurred in December with cooler temperatures. February also was cool but with a reverse pattern with small variation among stations (Figure 3). April/May exhibited little variation with higher temperatures to inland sites.

Broward and Dunn Creeks were consistently oligohaline while Clapboard Creek was oligohaline only in July and in the upper reaches in February (Figure 4). Good freshwater input is evident in Broward River and Dunn Creek as salinities stayed low even in the dry season.

There was no evidence of high oxygen demand as DO level were typically high enough for adequate biological production. Low readings were usually found in the early morning.

Table 3. Mean hydrological parameters and range in parentheses by creek and season.

Creek	Temperature (°C)	Salinity (psu)	Dissolved Oxygen (mg/l)
Broward			
July	29.5 (28.0-31.6)	2.4 (0.5- 5.8)	5.3 (3.4-7.2)
December	13.5 (12.0-15.0)	5.1 (1.5-13.0)	ND
February	18.4 (17.9-19.3)	5.9 (0.3-10.3)	6.6 (5.0-8.2)
April/May	28.0 (27.4-28.4)	2.1 (0.5- 4.5)	ND
Dunn			
July	30.2 (29.0-31.5)	3.9 (0.9- 8.9)	3.9 (2.8-4.6)
December	15.1 (14.0-16.6)	7.2 (1.0-13.0)	ND
February	16.4 (16.0-16.6)	6.1 (1.6- 9.4)	ND
April/May	26.2 (26.0-26.9)	3.0 (0.5- 7.5)	ND
Clapboard			
July	31.2 (30.5-32.1)	11.2 (7.0-14.0)	3.5 (1.3-4.9)
December	15.6 (15.0-16.2)	19.5 (14.0-25.0)	ND
February	17.7 (17.3-18.0)	21.4 (6.5-26.6)	ND
April/May	22.9 (22.2-24.4)	26.0 (21.9-27.4)	5.7 (4.7-6.5)
Cedar Point			
July	30.7 (29.6-33.2)	22.3 (19.5-24.3)	5.0 (2.6-7.9)
December	14.9 (14.1-15.3)	26.3 (24.0-29.0)	ND
February	14.5 (13.8-14.8)	28.8 (24.0-30.5)	7.5 (7.0-7.8)
April/May	18.5 (16.4-21.2)	28.7 (21.3-30.8)	6.7 (4.7-7.9)

ND – no data

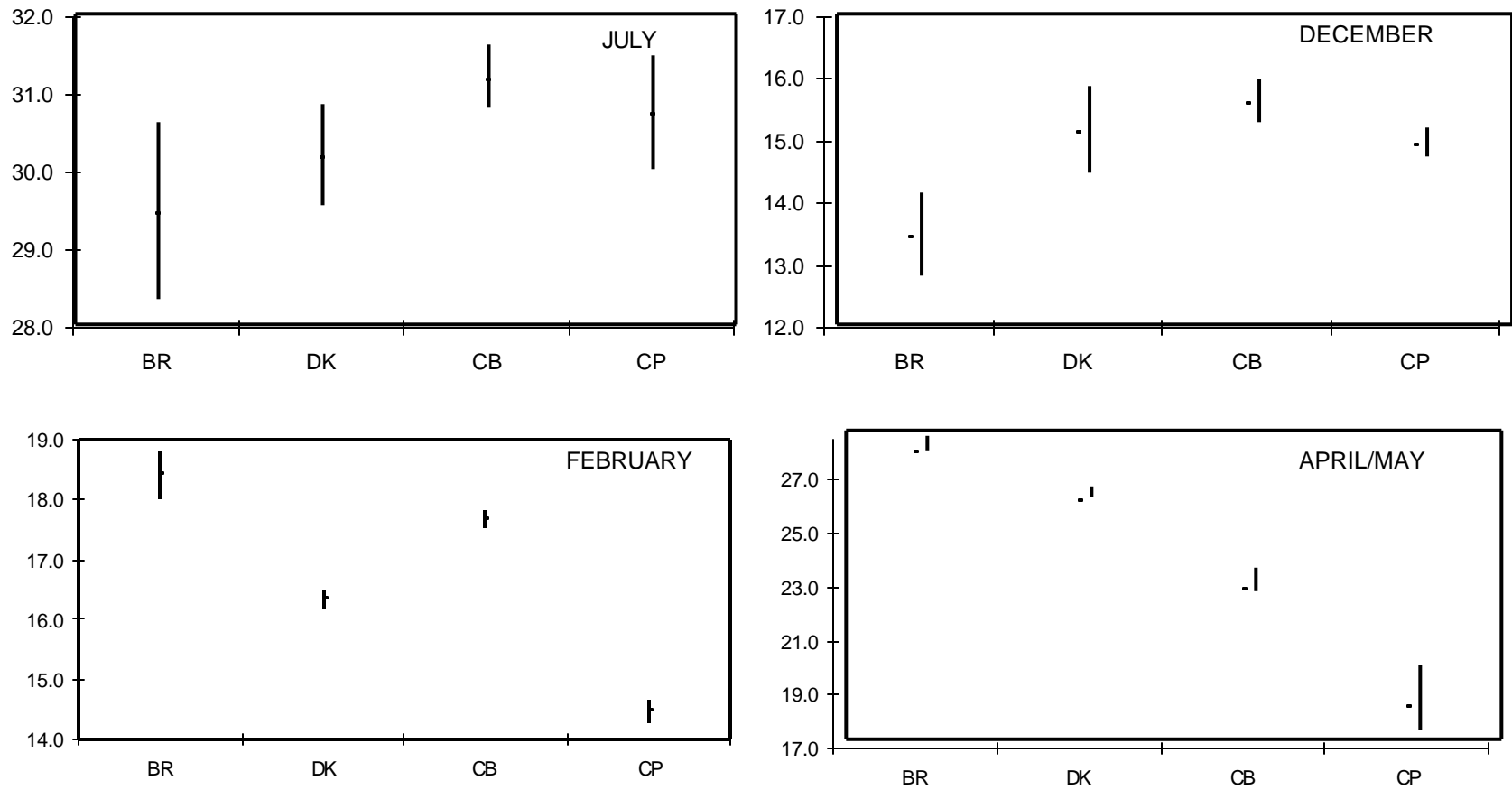


Figure 3. Water temperature (mean and 95% confidence interval) by creek and season. Bars that overlap are not significant different. BR – Broward River, DK – Dunn Creek, CB -Clapboard Creek, and CP – Cedar Point Creek.

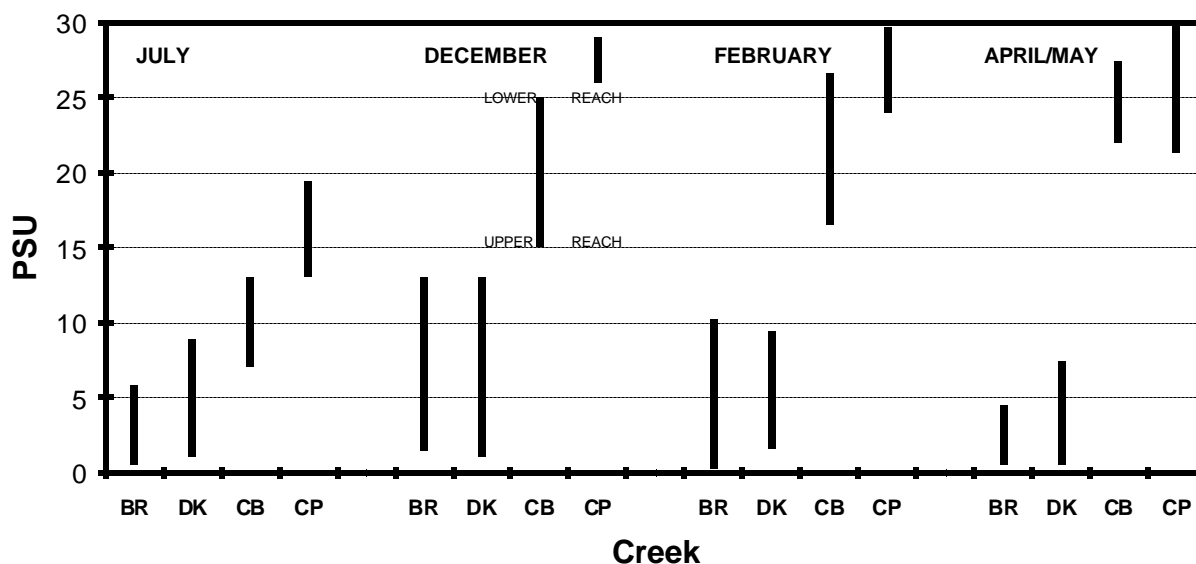


Figure 4. Salinity range for each creek by season.

Eighty-five taxa were taken by the trawl in 624 samples (Appendix Table A-1). Cedar Point Creek had the greatest fish abundance (due to bay anchovy *Anchoa mitchilli*) and greatest species richness (57 taxa).

All community parameters except evenness had significant interaction (Table 3). Examination of data plots show that overall Clapboard and Cedar Point Creeks have very similar trends while Broward River and Dunn Creek are similar. The two groups differ in having different seasons of peak abundance. This is illustrated for number of individuals (Figure 5). There was no difference in patterns among creeks and seasons in total number of individuals or only demersal taxa. There was great variation in abundance among seasons but trends are not the same among creeks. Broward River and Dunn Creek have similar patterns with peaks in July and April/May. Cedar Point Creek is most unusual with very low abundance in February resulting from major decline in bay anchovy that also included demersal taxa. The number of taxa or species richness had similar trends with abundance. Low abundance was accompanied by low species richness.

Shannon-Weiner diversity and Pielou's evenness exhibited similar trends with significant differences among creeks. Broward River had a December minimum in diversity with no decline in evenness. Clapboard Creek had an April/May decline in diversity with no attendant decline in evenness. Cedar Point Creek had a February decline in both diversity and evenness that was due to the lack of major taxa during this sampling period. Cedar Point Creek was significantly lower in evenness than other creeks due to the dominance of bay anchovy.

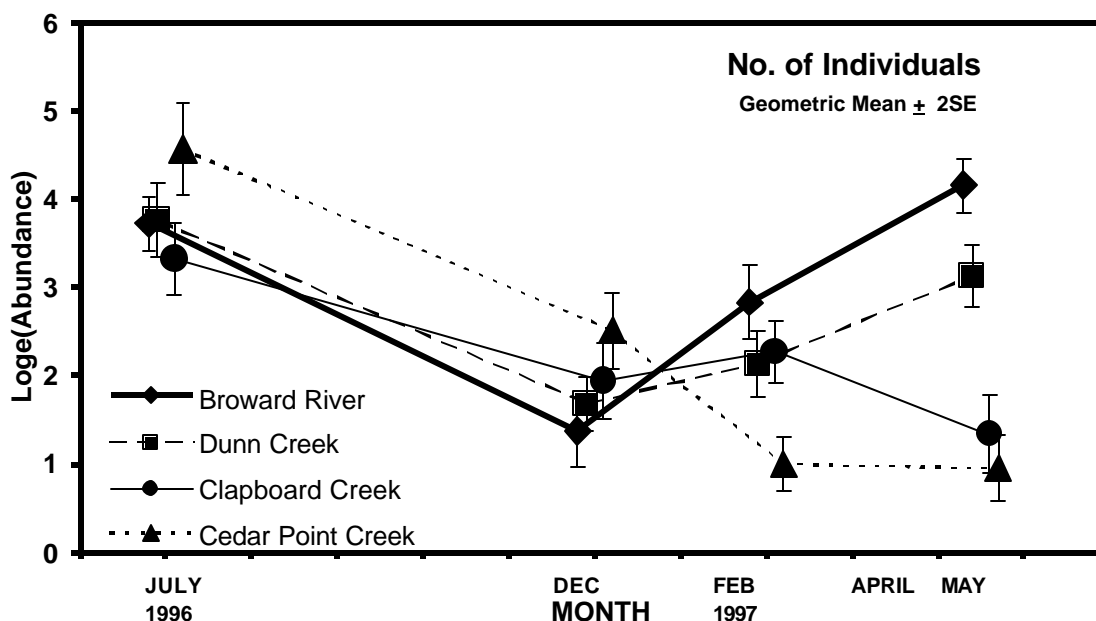


Figure 5. Total abundance of fishes by creek and season.

Table 3. Statistical comparison of community parameters and four most abundant species by creek and season.

Dependent Variable	Two-way ANOVA		
	Creek	Season	Interaction
No. of Individuals ¹	***	***	***
No. of Demersal Fishes ¹	***	***	***
No. of Taxa ¹	***	***	***
Shannon-Weiner Diversity	***	***	***
Pielou's Evenness	***	ns	ns
<i>Anchoa mitchilli</i> ¹	***	***	***
<i>Micropogonias undulatus</i> ¹	***	***	***
<i>Leiostomus xanthurus</i> ¹	***	***	***
<i>Trinectes maculatus</i> ¹	***	***	***

¹log_e(x+1) transformation used on these variables

ns – not significant

** - P>0.1

*** - P<0.001

The bay anchovy differed from all other species in greatest abundance in Cedar Point Creek with seasonal peaks in July and December. Both croaker (*Micropogonias undulatus*) and spot (*Leiostomus xanthurus*) had their greatest abundance in Broward River and Dunn Creek with April/May peak in recruitment. Croakers were dominant in Broward River while spot were more abundant in Dunn Creek (Figure 6). There was no difference in spot abundance between the two creeks during April/May peak, but Dunn Creek had an additional peak in July. The hogchoker (*Trinectes maculatus*) was uncommon in Cedar Point Creek and Clapboard Creek. A single peak in abundance occurred in July in both Dunn Creek and Broward River.

Cluster analysis shows that seasons had greater affinity than creeks (Figure 7). There are four major clusters with December samples from Dunn, Clapboard and Cedar Point Creeks being most dissimilar (group 4). In contrast to the seasonal similarity Broward River samples from July, December and February were very similar (group 1). Other creeks were similar to Broward River only in April (group 3).

DCA identified groups of taxa that define creek and seasonal conditions. Axis 1 separate taxa, such as pigfish (*Orthopristis chrysoptera*), green goby (*Microgobius thalassinus*), Atlantic silverside (*Menidia menidia*), scaled sardine (*Harengula jaguana*), naked goby (*Gobiosoma bosc*), and bay whiff (*Citharichthys spilopterus*), that were most common in Clapboard and Cedar Point creeks (Figure 8). The lower part of axis 2 groups four taxa, hogchoker, freshwater goby (*Gobionellus shufeldti*), gizzard shad (*Dorosoma cepedianum*), white catfish (*Ameiurus catus*) that used fresher conditions in Broward River and Dunn Creek (Figure 8). The third axis separates out spot, croaker, blackcheek tonguefish (*Symphurus plagiusa*), and weakfish (*Cynoscion regalis*) that had major recruitment in April/May and July (Figure 8).

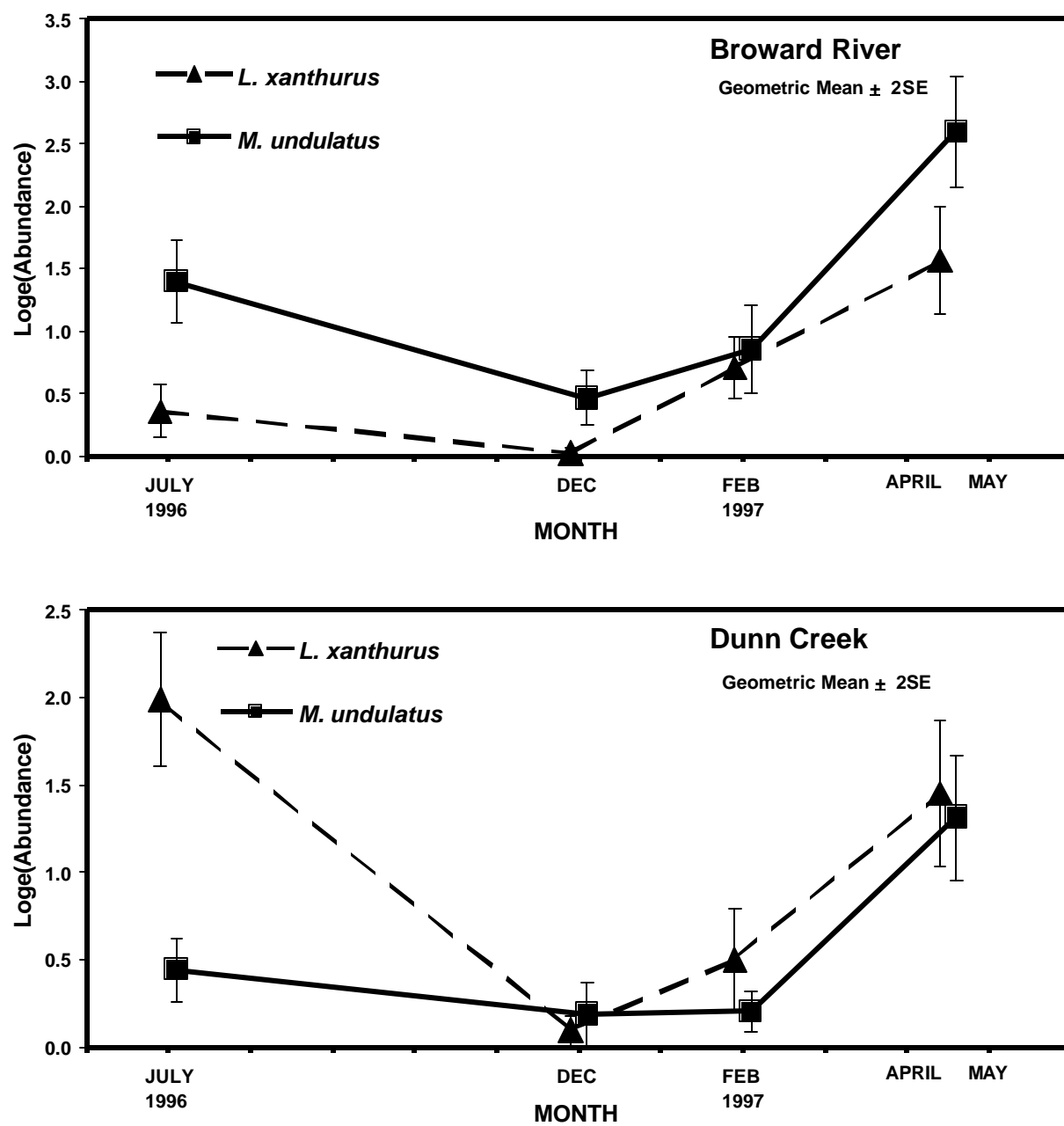


Figure 6. Abundance of spot (*Leiostomus xanthurus*) and croaker (*Micropogonias undulatus*) by season for Broward River (upper) and Dunn Creek (lower).

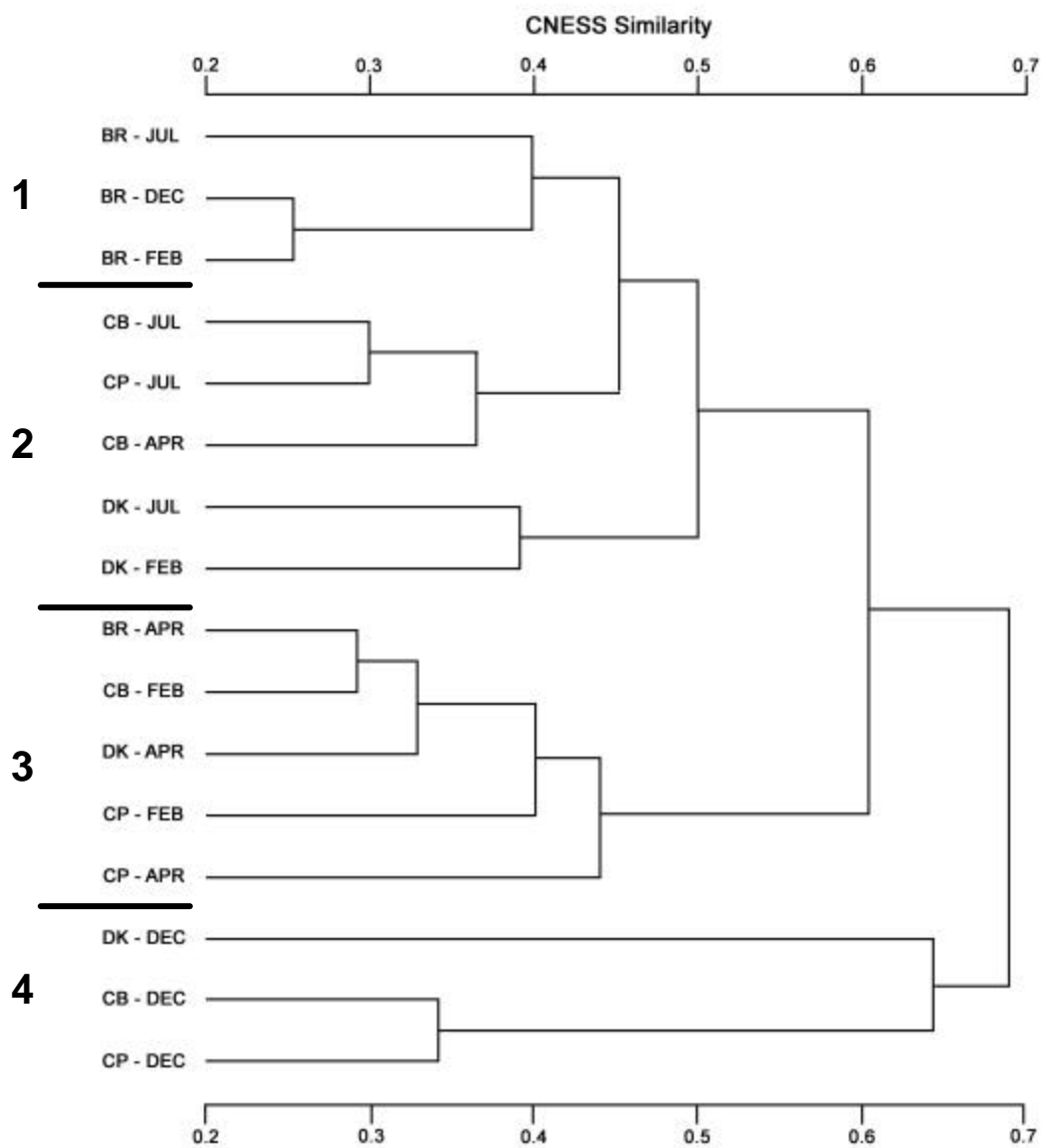


Figure 7. Clustering of creek-season samples using CNESS similarity and UPGMA.

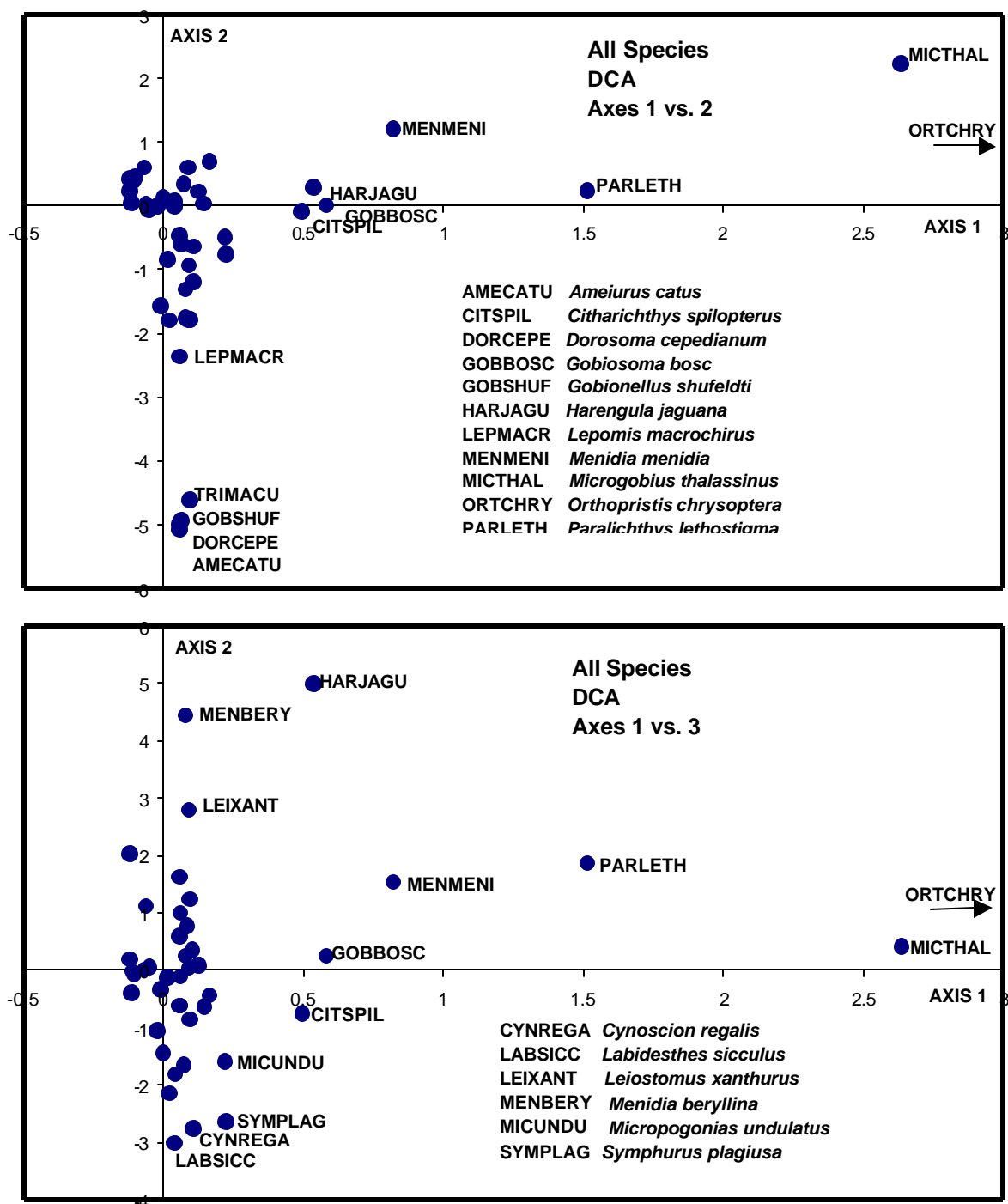


Figure 8. Detrended correspondence analysis for major taxa. Taxa that contribute to differences among creeks are labeled.

Discussion

Creeks differed across the gradients of freshwater input and urbanization gradients. The two gradients coincided (both declining as you move from west to east); making identification of the dominant factor affecting fish assemblages difficult. However, fundamentally, the distribution of fishes was highly correlated with salinity conditions. Consistent assemblages have identified across estuaries along the US Atlantic coast and Gulf of Mexico (Bulger et al., 1993; Christensen et al., 1997). The importance of the oligohaline habitat can be recognized by its use as a nursery area for such species as croaker, spot, weakfish, and hogchoker. Croaker and spot exhibit the typical pattern of juvenile recruitment and back filling estuaries with smallest individuals found in the upper reaches of the creeks (Weinstein et al., 1980; Miglarese et al., 1982; Rogers et al., 1984). As these fish mature they move toward the ocean making use of more saline habitats such as Clapboard and Cedar Point Creeks.

Oligohaline conditions allow an admixture of freshwater and euryhaline species increasing the diversity of the system (Rozas and Hackney, 1983). Euryhaline species dominate oligohaline habitats in this area similar to other Atlantic Coast sites (Rozas and Hackney, 1984). Use of all creeks by fish was greatest during the wet season when salinity was lowest. Broward River and Dunn Creek were similar in sharing freshwater species, such as, sunfishes (*Lepomis* spp.) and white catfish. Clapboard and Cedar Point creeks were similar due to the presence of polyhaline taxa. Weinstein et al. (1980) identified a clearly defined ecotone with the mesohaline-polyhaline transition zone. This increases the diversity of the fish assemblage by allowing the presence of stenohaline marine taxa. The greater species richness of Cedar Point Creek is expected from its position nearer the ocean allowing the use of these marine species. This higher species diversity and richness has been observed in other systems (Frazer, 1997) but should not be construed as improving the environment by increasing salinity.

While human alterations can reduce the value of estuaries as nursery grounds (Felly, 1987) there appeared to be little measurable impact of urbanization in the present study. The most developed creeks, Broward River and Dunn Creek, were used as nursery areas for many species. In other studies where substantial alteration has occurred, a significant drop in number of fish and species has been reported (Taylor and Saloman, 1968; Lindall et al., 1973; Vernberg et al., 1992). This has been attributed to reduced oxygen levels due to poor circulation. The tidal

creeks sampled here did not suffer this problem as they were flushed daily by the tide. Even in the most developed creek, Broward River, bulkheading and shoreline alteration was minimal leaving a marsh fringe. Retention of critical shoreline shallow-water habitat may have contributed to the health of fish community found there.

Felley (1987) found hogchoker, bay whiff (*Citharichthys spilopterus*), naked goby (*Gobiosoma bosc*), southern flounder (*Paralichthys lethostigma*), and gulf pipefish (*Syngnathus scovelli*) as rare or absent from altered tidal creeks in Louisiana. All these taxa were found in Broward River and Dunn Creek suggesting good health in these systems.

Where extensive estuarine alteration has been reported, pelagic species such as bay anchovy dominant (Bechtel and Copeland, 1970; Lindall et al., 1973; Livingston, 1975). Bay anchovy were extremely abundant in lower Cedar Point Creek during July. This unusual abundance was near the mouth of the creek that is obstructed by a culvert under a causeway. Thus, poor circulation may have resulted from this alteration. Good lateral connections to Clapboard and Sister's Creek further upstream may moderate the impact of the obstructed creek mouth (Figure 1).

Wetland alteration is the most important issue affecting coastal fisheries resources in northeast Florida (Durako et al., 1988). Wetlands should be treated as a nonrenewable resource. Preserving wetlands protects critical fisheries habitats and maintaining freshwater inflow provides substantial marginal value to wetlands (Swallow, 1994). Increasing populations in the Jacksonville area will result in increased demand for freshwater, increased wastewater output, and further alteration of runoff characteristics in the area. Protection of the freshwater input to Broward River and Dunn Creek is critical to maintaining the nursery function. While these creeks lay outside of the NPS Preserve, their alteration will have an impact on the Preserve by changing the source of recruits for species, such as spot and croaker, that make use of high salinity habitats later in their life cycle.

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